Annual mowing of a grassland had minimal effect on botanic composition during a period of changed climate (or prolonged drought)

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Abstract
Prolonged drought, as has been experienced over much of the wheat-sheep (or grassy woodland) zone of southern New South Wales during approximately the last 15 years, is equivalent to a change in climatic zone from subhumid to semi-arid. One of the symptoms of this is less reliable rainfall, particularly during the normally dependable autumn-winter period. As demonstrated by the results of a 7-year experiment in a grassland near Molong in Central Western NSW, this change, if permanent rather than temporary, has implications for ecological experiments that aim to change botanic composition using various manipulatory techniques. At Molong, significant differences in botanic composition were evident over time but not between treatments. It is suggested that this result can be explained by the prevailing rainfall regime during the period of observation and that different results may have been obtained if rainfall had been more closely aligned to the long-term average. (*The Victorian Naturalist* **127** (5), 2010, 168-173).

Keywords: cool-season rainfall, derived grassland, gap-creation, mowing

Introduction

On the inland slopes and plains from central New South Wales (NSW) to Victoria, cool-season (autumn and winter) rainfall is a major driver of landscape processes. These include the refilling of wetlands, the flush of growth of cool-season plant species, and the replenishment of subsoil moisture for growth of warm-season species over summer when rainfall is less effective. A key feature of cool-season rainfall in this area has been its reliability — a feature that also has permitted successful farming in the 'wheat-sheep' belt, the subhumid climatic zone (usage according to Read 1994) formerly occupied by grassy woodlands; however, in recent years, cool-season rainfall has been far from reliable. An analysis (Semple *et al.* in press) of cool-season (March-August) rainfall from 1885–2008 at Cowra NSW indicated that, in terms of rainfall received and the frequency of below-average* seasons, the 15-year period 1994–2008 was drier than any other equivalent period since records commenced. Whether this can be considered another prolonged drought like those that occurred at the turn of the 19th century and in the mid-20th century, or a result of a permanent change in climate, is still being debated. However, as noted by Read (1994), prolonged drought results in at least a temporary change in climate; and, in the wheat-sheep belt, this has resulted in a change from a predominantly subhumid climate to a semi-arid climate.

A characteristic of many semi-arid and arid lands is high variability in annual rainfall that results in varying levels of abundance of plant species in the groundstorey with time. In their summing-up of vegetation ecology and management in Australia's rangelands, Harrington *et al.* (1984: 60) emphasised the differences between reliable and unreliable climates as follows:

> 'In a reliable climate ... it is possible to plan a grazing and/or fire management regime which is responsive to the rainfall regime and takes into account the life-histories of the key plant species, and thereby obtain a measure of control over the composition of the plant community. In unreliable climates the acquisition of such knowledge is much more difficult because any particular run of rainfall events is infrequently repeated and may give an effectively unique vegetation response.'

*Throughout this report, 'average' is equivalent to mean.

The effects of drought on components of the flora include failure to germinate, germination followed by early death, reduced seed production, and death of perennial species. When aggravated by chronic overgrazing, a permanent change in groundstorey composition may occur, as has been reported in the semi-arid rangelands (e.g. Noble 1997). Rains do occur during prolonged drought but in lower amounts during the season when they are expected (at least in most years), and heavy rainfalls may occur at unexpected times (e.g. see warm-season rainfall for 2005/06 in Fig. 1). In the latter case, some species may be advantaged by low groundcover and/or the absence of species that normally would be present.

This raises the question of whether the results and conclusions of 'paddock-scale' experiments (i.e. those involving assemblages of organisms) carried out in more benign times, when cool-season rainfall was adequate and reasonably reliable, are applicable during a prolonged period of unreliable rainfall. Conversely, will the results of field experiments carried out in the last 10 or 15 years be applicable when or if rainfall returns to a level that is more closely aligned with the long-term average?

Among the paddock-scale experiments that could be affected by a change in climate (temporary or permanent) are those relatively long-term studies that attempt to manipulate groundstorey composition by one-off or sequential biomass-removing disturbances such as crash grazing, burning and mowing. Such disturbances create canopy gaps that, depending on the time of year they are created and on the type of groundstorey, may be beneficial (e.g. Morgan 1998) or deleterious (e.g. Lunt 1990) for biodiversity conservation. Gap-creation exercises are likely to be ineffective in environments that are limited by low rainfall (e.g. semi-arid rangelands) and/or low fertility, as gaps are usually already present (Lunt 2007).

One site selected for such an experiment was in derived grassland in an unused part of the cemetery at Garra, 10 km west-south-west of Molong, on the Central Western Slopes of NSW. The site was fertile, dominated by exotics (a probable consequence of grazing many years previously) and Speargrasses (*Austrostipa** spp.). It was hypothesised that, depending on the time that gaps were created by mowing, different species would be favoured whereas others would be discouraged if they were seeding at the time mowing occurred. All slash was removed, as this was considered to discourage exotics (e.g. see Verrier and Kirkpatrick 2005) and could be compared to crash grazing where selective grazing is negated.

* Botanical nomenclature follows that of Harden (1990-93).

An implicit assumption at the time the experiment commenced in 1999 was that rainfall would be 'average', i.e. approximately 350 mm in the cool-season with a similar, though less effective amount, in the warm-season. As can be seen from Fig. 1, this did not occur. Severe deficiencies occurred in 2002 and 2006, and cool-season rainfall was below average every year after 2001.

Methods

The experimental area was divided into 18 contiguous 6 m x 5 m plots: three rows (blocks) of six treatments. The five mowing treatments, annual mowing in either mid-summer, mid-autumn, mid-winter, mid spring, or mid-autumn + mid-spring, and unmown were randomly allocated to plots in each block. At each mowing, herbage was cut to a height of approximately 4 cm and clippings removed by hand raking. Treatments were applied in the relevant season(s) from summer 1999/2000 to spring 2007. Abundance of species in each plot was assessed in December 2000, October 2001, November 2003 and October 2005 using Outhred's frequency-scores as described by Morrison *et al.* (1995) [obtained by laying out seven rectangular quadrats that increased geometrically in size from the inner to outermost quadrat, and recording presence/absence of rooted plants of each species in each quadrat]. Individual species in each plot were also assessed semi-quantitatively using a modified Braun-Blanquet 0-7 cover-abundance scale in October 2007.

After eliminating 11 species recorded in only one plot and on only one occasion, the remaining species were examined in two ways:

The data matrix of the 71 species was converted to a similarity matrix using Bray Curtis similarity coefficients contained within the PRIMER (Version 5) statistical package (Clarke and Gorley 2001) and analysed using non-metric Multi-Dimensional Scaling (MDS). The degree of association of individual plant species with the treatments and times and their interactions was measured by Indicator Species Analysis us-

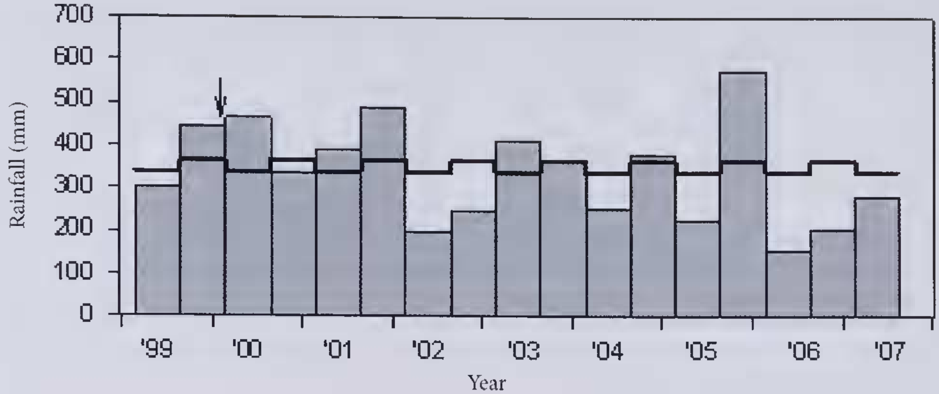

Fig. 1. Cool (March-August) and warm (September-February) season rainfall at Molong (Bureau of Meteorology Station 065023) prior to and during the mowing experiment at Garra. Thickened line indicates long term (1884-2007) seasonal means. Arrow indicates the initiation of mowing.

ing PC-ORD (McCune and Mefford 1999). The indicator value is maximal (IV=100) when all individuals of a given species are restricted to a particular treatment or time, and all samples from the particular treatment or time contain an occurrence of that species.

Univariate analysis of variance was performed on mean frequency-scores and mean numbers of species within species groups, viz. native perennials (33 species across all plots and times), native annuals/biennials (6 species), exotic perennials (6 species) and exotic annuals/biennials (26 species).

Results

Differences in species composition between treatments were undetectable until 2005 when a marginal difference ($P = 0.06$) between the unmown control and the treatment with the highest level of disturbance, viz. spring+autumn mowing, was evident.

However, the occurrence and abundance of many species was very time-dependent. The Indicator Species Analysis showed that the abundances of approximately half the species were significantly higher ($P \leq 0.05$) in a particular year: for eight species in 2000, another six in 2001, three in 2003 and 15 in 2005.

Univariate analyses also indicated significant differences ($P \leq 0.001$) in the mean frequency-scores within all species groups over time (e.g. Fig. 2) and in the mean numbers of species within the groups, except for exotic perennials. Differences between treatments ($P \leq 0.05$) were not detected except for the small group of native annuals/biennials. Visual inspection of the graph of the latter (Fig. 2a) suggested that differences were highest in late 2005 when mean frequency-scores in the spring and autumn+spring mowing were elevated relative to the control — a trend that also was evident in the cover-abundance data for late 2007.

A distinctive feature of the results was the number of species that were recorded in only one or two seasons. Of the 82 species/species groups that were observed in the four quantitative observations, together with another two that were observed only in the last (semi-quantitative) observation in 2007, 25 were infrequently-recorded: 13 in only one season and 12 in only two seasons. At the last observation in 2007, 29 species (of which 17 were in the infrequently-recorded group) were absent and 12 of these were also absent at the previous observation in 2005. Amongst the last-mentioned were the once relatively common weeds, Viper's Bugloss *Echium vulgare*, Salsify *Tragopogon porrifolius* and Twiggy Mullein *Verbascum virgatum*.

Discussion and conclusions

The results suggest that the effects of annual mowing in different seasons had minimal effect on species composition over a 7-year period. Some minor differences between treatments were evident in 2005, but whether they were a result of cumulative mowing effects (as was expected) or seasonal effects (2005 was an unu-

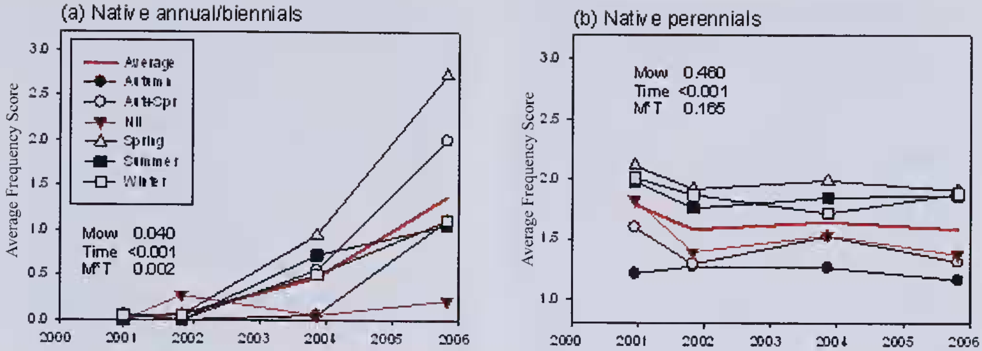

Fig. 2. Mean (n = 3) frequency-scores for (a) native annuals/biennials and (b) native perennials in all treatments at Garra from mid December 2000 to late October 2005. *F* probabilities from ANOVA for mowing treatment effect, time effect and their interaction are shown within each graph.

sual year with well above-average spring rainfall) is uncertain.

There are a number of possible explanations for the lack of treatment effects. Firstly, it could be argued that the monitoring technique was insufficiently sensitive to detect changes in species composition. The methodology put the observer in close proximity with the plants present in each plot and it is believed that all species present were detected. However, the process was somewhat destructive, particularly during dry times, and was the main reason why the technique was discontinued after 2005. Furthermore, the technique did not distinguish between healthy plants and those that were drought-affected.

Secondly, the annual (and in one treatment, biannual) mowings may have been too benign to have had any measurable effect. This was unlikely, as the aim of the mowing was to create gaps in the vegetation and to remove seedheads at particular times of the year, however, as discussed below, seedhead production was seasonally variable and gaps were not always fully exploited. In any case, even biennial mowing has been reported to affect grassland structure and species (albeit cryptogam) composition (O'Bryan *et al.* 2009).

Thirdly, it could be argued that the type of groundstorey, e.g. with a preponderance of naturalised species, was inherently stable and unlikely to change. Yet this was not the case as groundstorey composition changed significantly from year to year regardless of treatment, a result that would be expected in a more semi-arid region subject to variable rainfall.

The most likely explanation for the lack of expected differences between treatments was the variable and often below-average rainfall that prevailed for most of the time the experiment was carried out. This is not a novel explanation. Following pasture manipulation, including slashing, experiments at four sites during 1993-96, Garden *et al.* (2000) reported minimal difference between treatments and attributed the result to prevailing drought. With respect to two sites, they noted that changes in pasture composition occurred only 'when rainfall returned to average or above average after at least 12 months of drought' (Garden *et al.* 2000: 243). Perhaps the marginal differences between treatments that we observed in 2005 were akin to this.

Without sufficient rainfall at appropriate times, it is unlikely that gaps will be fully colonised and it was noted at Garra that as dry conditions intensified after 2001 there was always some bare ground (gaps) in the treatment plots; so in this respect, any one treatment was much the same as another. Furthermore, the production of seedheads was variable over time, particularly in the case of Speargrasses where seed crops were minimal in some years. Removing seedheads by mowing and raking at the time they were normally produced would have had little differential effect if few seedheads were present anyway. Furthermore, Speargrasses can reappear after suitable rainfall despite being absent for many years, suggesting that they have persistent seedbanks (Grice and Barchia 1992). Hence, raking may not have had a dramatic effect on subsequent germination.

More importantly, however, was that the abundance of many species was significantly aligned with a particular season; i.e. the composition of the groundstorey in all treatments, including the control, was changing throughout the period of observation. This was more consistent with observations in semi-arid and arid areas where groundstorey composition can vary markedly from year to year. Different plant functional groups use water at different times, and vary in the efficiency with which they use rainfall of differing duration, intensity and amount (Westoby 1979/80). This creates opportunities for different communities to develop in response to differing modes and types of rainfall, favouring different suites of species depending on the rainfall. Increasing rainfall variability increases the dominance by annuals, and studies of annuals in more arid areas (e.g. Tobe *et al.* 2005), indicate that rainfall regime is the most critical factor affecting variable establishment successes of different annual species.

We do not know to what extent results of this experiment would have been different in 'normal' or even high rainfall years and we are most reluctant to generalise our findings to those conditions. We suspect, however, that much of what we observed at Garra was a consequence of variable and often insufficient rainfall as well as a progressive drying of the site.

Our results are probably more consistent with expectations from the semi-arid zone (Mott 1972) than from the subhumid to humid zones. In the former, changes in a chronic management regime may take a longer period to become evident — or, as noted by Westoby *et al.* (1989), be particularly dependent on an infrequent environmental event.

Regardless of whether or not readers accept our suggestion, viz. that the results may be applicable to another (less favourable) rainfall zone than the one in which the site was nominally located, a question remains: are the results of experiments carried out during drought relevant to ecology? In the case of an 'ordinary drought' or an extended dry period extending across one or two years, our knowledge is perhaps sufficient to predict the consequences on assemblages of plant populations. But in the case of exceptionally prolonged drought that occurs once in a century, we clearly do not have sufficient information — unless we are prepared to extrapolate findings from adjacent drier climatic zones.

For years, farmers and graziers have been advised (e.g. Heathcote 1969) that droughts are normal events for which they should be prepared. Following each of the droughts of recent years, information, predominantly anecdotal, has been compiled into 'effects and lessons from the drought' publications (e.g. Malikides *et al.* 1969; Austin *et al.* 1995). As a result of predictions of more frequent and severe droughts due to 'climate change' (e.g. Stokes *et al.* 2008), advice on drought effects has become more urgent. Yet what do experimental field ecologists do when the expected rains do not occur during their usual 3-year time-frame? Some are advised by their supervisors to irrigate their plots 'up to average rainfall' or carry out concurrent glasshouse pot trials. Altering experiments in such a way may mean that we lose the opportunity to learn more about the consequences of a more variable and sub-average rainfall regime on more mesic ecosystems. Nevertheless we acknowledge that some specifically drought-oriented ecological reports have been published recently (e.g. Croft *et al.* 2007; McKeon *et al.* 2009) and hopefully more will follow.

Much can be learned about the response of more mesic vegetation communities to reduced and more variable rainfall by observing how semi-arid plant communities respond to rainfall variability. In the case of our study at Garra, the plant community exhibited a response to rainfall that was typical of a semi-arid community. Results of studies such as ours — even if 'negative' — may provide valuable guidance if the change in climate from subhumid to semi-arid becomes permanent rather than temporary.

Acknowledgements

The experiment was funded by the former NSW Department of Natural Resources (part of which has since been incorporated within the Department of Environment, Climate Change and Water) with the support of the Cabonne Council. John Young and Ian Cole assisted in the field and David Eldridge analysed some of the data. David Eldridge and David Cheal provided valuable commentary on the manuscript. Thanks to you all.

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Received 10 September 2009; accepted 22 April 2010

One hundred years ago

EXCURSION TO WEST WARBURTON

A.D. Hardy

From "The Rock," in suitable weather, a magnificent view can be obtained, and for this alone the climb is justified. The day was too hazy to make out through our field-glasses any of the prominent, land-marks of Melbourne, forty miles away, but the pine trees on the hill at Ringwood were distinctly visible, while Mounts Macedon and Baw Baw, about a hundred miles apart, bounded our view to the west and east. To the north the sharp cone of Mt. St. Leonard was just visible through the trees. We looked over " Nyora," and Malleson's Look-out to Healesville, but the most delightful view was down into the Yarra valley, nearly three thousand feet below us, where the three townships of West Warburton, Millgrove, and Warburton were prominent features. An apparently level ridge led round eastwards to Donna-Buang, while southwards range and valley succeeded one another as far as the eye could reach. The position of Gilderoy, where we had intended to explore, could just be made out among the ranges about ten miles to the south-east. We returned by a more direct route, and from the Dee valley brought away several species of ferns and seedling plants, including an Eriostemon, probably *E. squamens*, some of which are destined to find their way into public gardens after a period of pot-life.

From *The Victorian Naturalist* XXVI, pp. 188-189, April, 1910